Initial Study of Solar Control Film in a Hotel Guest Room in Winter

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Abstract: In recent years, energy-efficient facilities have prevailed in the Hong Kong and China markets. Many of these facilities claim to generate considerable energy and money savings. Hoteliers, however, find that there is a lack of independent and local studies about energy performance and its related financial savings and environmental improvement brought by those facilities, such as heat pumps, solar-control film on the window, sensor and dimmer for lighting control, etc. Nevertheless, there is a lack of reliable and independent data about the energy performance and economic viability of the solar-control film applied in a real environment. In many situations, consumers are only given the laboratory's result of this energy saving facility. Research was carried out in summer to estimate its positive effect on energy saving. There is also a paucity of experiments conducted in winter to show its negative effect in cold weather. This study carries out an experiment in hotel guest rooms in winter in order to estimate the energy and lighting performance of solar-control film in winter. This experiment was conducted when the illuminance under 1000lux, the average visible light transmittance for the film was 49.8%, and with very low solar radiation being transmitted into indoor environment. Under these situations, the study found that the effect of solar energy passing through the film coating in the guest room can be neglected. Instead, the film can act as a layer to prevent heat to transmit to the outdoors, just like the greenhouse effect.

Key words: energy efficiency; solar-control film; hotel guest room; field study; winter

1. INTRODUCTION

Due to increasing hotel supply, subsequently keen competition and rising operational costs in Southern China's hotel market, hotel industry's profitability in the area has experienced a decline in the past few years. Official publications indicate that room rates in place like Hong Kong have reduced substantially since 1996[1,2]. Due to the difficulty in raising revenue, many hotels had exhausted almost all the means to retrench costs. Almost all types of operating costs have undergone different degrees of reduction except energy cost, which is relatively fixed by nature that means it is difficult to be cut down. However, energy is a major operating cost in hotel operations. Energy consumption in hotels in the area had risen a lot due to tourism boom and hotel expansion in the past two decades. For Hong Kong, hotel energy consumption had an increase of 41% over past thirteen years[3]. Any long lasting saving in this area will definitively mitigate the pressure of tightening expenses. Thus, there is a need for looking into some more energy-efficient and economically-viable equipment to replace existing energy-driven systems and equipment. As a result, different energy saving facilities currently prevailing in the market attracts both researchers and consumers' attention.

In subtropical climates, the principal objectives of fenestration design include eliminating direct sunlight decreasing cooling loads[4]. Daylight is always accompanied by solar heat gain. The benefits from daylight may be penalized by the corresponding increase in solar heat gain. Moreover, because of the small angle of incidence, direct sunlight can be excessive for east- and west-facing windows in early morning and late afternoon. To avoid the problems of glare, excessive brightness and thermal discomfort, occupants may block the windows with internal shading devices, resulting in poor day-lighting performance, switching on electric light fittings and completely isolating with the outdoor environment. Recent advances in thin film coatings for window glass product provide a means of substantially reducing heat gain without proportionally reducing daylight transmittance. It is expected that solar-control film coating could minimize electric lighting and cooling requirements without causing undue visual and thermal discomfort to the occupants. Effective elimination of the direct solar component can shift the time for peak cooling load and decrease significantly the cooling plant capacity. The most important information for solar-control films would be their optical properties including solar heat and light transmittances[5]. The solar energy and light transmittances of solar control films are mainly correlated with the angle of incidence[6] and wavelength[7] based on experimental data conducting in laboratory. The long-term energy performance and life cycle cost of solar control film have been investigated using computer simulation techniques [8].

Nevertheless, there is a lack of reliable and independent data about the energy performance and economic viability of the solar-control film applied in real environment. In many situations, consumers are only given the laboratory's result of this energy saving facility. In addition, there are very limited research reports. Most importantly, the available ones are carried out in summer to estimate its positive effect on energy saving. Nearly no experiment is carried out in winter to show its negative effect in cold weather. This study carries out an experiment in hotel guest rooms in winter to estimate the energy and illumination performance of solar-control film in winter.

2. METHODOLOGY

This study conducted a field experiment in Feb. 2006, in a three-star hotel in Xiangtan City, Hunan Province. The research lasted for three days, eight hours per day, from 8:00 to 22:00. The object is a T-shaped five-layer hotel building, located in the central urban area of the city and by the side of a crossroad. These site characteristics enable the hotel to receive direct sunshine without being sheltered by other higher building nearby. Central air-conditioner was adopted for cooling and heating in whole building.

This experiment selected two standard guest rooms near east side on the fifth floor which has windows facing south. Figure 1 shows that these two selected guest rooms have the same area, orientation, decoration, and furnishing; the dimension of window is 1.9m wide and 2.0m high, thickness of which is 5mm. During the experiment, nobody was in either room. The potential heat sources like light and TV were stopped. The blowing velocity of air-conditioner and recirculated air temperature were both set as middle level and 25 , respectively. The only difference between these two rooms was that window of Room 1 was coated with a layer of solar-control film, while Room 2 was not. The film selected is a kind of world-wide popular product, whose manufacturer-claimed technical data is presented in Table 1.

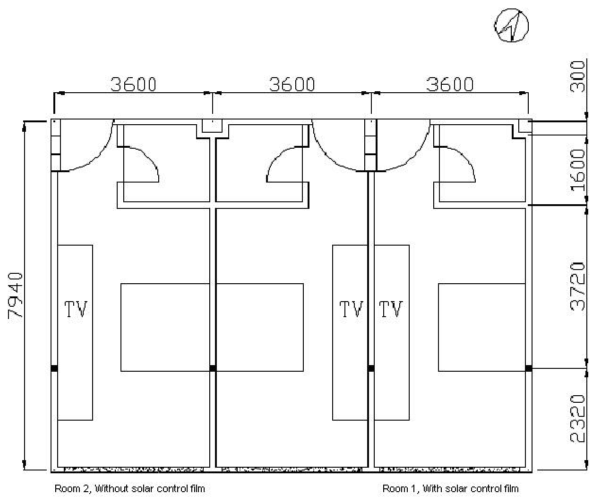

Fig.1 Dimension of selected guest rooms

Tab.1 Technical data of selected solar-control film

Index	Unit	Data
Sheltering Coefficient		0.66
Visible Light Transmission	%	51
Visible Light Reflectivity	%	15
Solar Energy Reflectivity	%	10
Solar Energy Absorptivity	%	45
Solar Energy Transmission	%	45
Total Solar Energy Rejection	%	43
Ultra-Violet Rejection	%	99
U-Value		1.06

The target parameters of this experiment are heating load of guest room, outdoor solar radiation intensity, indoor illumination, and indoor plus outdoor temperature. The measurement of heating load was made by means of rotermeter (SPX 20mm, U.S. Haifu) and thermometers (PTWD-2A), which were adopted to measure the flow rate and inlet, outlet temperature of heating water in fan coil of the guest room, respectively. A pyranometer (TBQ-2A, Jinzhou 322) was horizontally installed 300mm outside external wall to measure outdoor solar radiation intensity; Indoor illumination data was logged by illuminance meter manufactured by Beijing QJHB Co. Limited (Model: LT/G). And the instruments for indoor and outdoor air temperature and relative humidity sampling were manufactured by TESTO, Germany. All the instruments were connected to a 24-Channel data logger (EN880-05, Beijing Yinghuada Electronic Co.). The measured data was transferred to this data logger and was recorded at 1-minute interval.

3. RESULT AND DISCUSSION

During these three measurement days, weather in Xiangtan City was continued to be cloudy. Short period of sunshine only appeared at noon time of Day 2. As can be seen from Table 2, the average outdoor air temperature (Ta) was 11 , the max. and min. temperature were 18.5 and 3.6 , respectively. Relative humidity (RH) ranged from 46.03% to 96.85%. The lowest RH appeared only during the short sunny noon time. In most cases, RH were relatively high-over 60% recorded data were higher than 70% with an average value of 71.73%. For the solar radiation, its intensity was less than 400w/m^2, except the sunny time since the weather during the experiment was cloudy in most of time. In a word, these three days can represent the typical climate in winter of this region.

Tab.2 Outdoor climatic data during experiment

		Day1	Day2	Day3	Aver
Ta ( )	Aver	7.6	13.0	12.9	11.0
	Max	18.5	18.5	15.0	18.5
	Min	3.6	5.0	10.8	3.6
	S.D.	1.6	3.6	1.1	3.6
RH (%)	Aver	77.12	66.45	71.78	71.73
	Max	88.69	96.85	86.45	96.85
	Min	65.59	46.03	63.59	46.03
	S.D.	6.03	13.55	6.45	10.66
Solar Radiation (W/m^2)	Aver	95	207	50	125
	Max	398	890	198	890
	Min	0	0	7	0
	S.D.	91	194	37	147

To evaluate the illuminance performance of the solar-control film in winter, data of one typical experiment day (Day 1) was selected, which is shown in Figure 2. Due to the cloudy weather, indoor illuminance was quite low. Only in the half of an hour from 9:30 to 10:00 when sun shine appeared, indoor illuminance level had an obvious elevation. As it can be seen from Figure 2, similar trends can be observed from the two curves of test two rooms. Compared to prior work[9], it seems that this sort of solar control film can reduce even larger amount of daylight illuminance when the outdoor illuminance is below 1000 lux than when outdoor illuminance is over 5000 lux. The result of this experiment showed the average visible light transmittance for the film was 49.8%, far lower than the previous study of 76.7% (Danny H.W. Li, et al., 2004). The difference was caused by the relatively low base illuminance value of this study. In addition, little daylight resistance during the measurement period can result in a large resistance percentage.

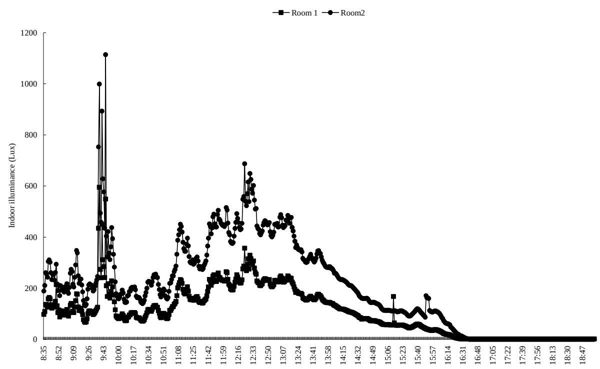

Fig.2 Measured minutely daylight illuminance profiles on Day 1

This study tries to calculate heating consumption via measuring the instant flow rate and temperature decline of the heating water through fan coil. The formula is shown below:

$$E = \int \frac{F \cdot \rho \cdot C_p \cdot \left(T_{in} - T_{out}\right)}{3600} dt$$

in which: E: Air-conditioner's heating load (kJ);

F: Heating water flow rate through the fan coil (m^3/h);

ρ: Density of water (kg/m^3);

C_p: Heat absorption capacity of water (kJ/(kg));

T_{in}: Inlet temperature of heating water through the fan coil ( );

T_{out}: Outlet temperature of heating water through the fan coil ( ).

Surprisingly, the calculated result was just opposite to our common sense. Naturally with something coated to the window glass to resist the solar radiation from outdoor, we may assume the heating load should be raised in winter because of less heating gain from outdoor. The calculated total heating energy consumption in Room 1 (with film coating) was 617000kJ, while the energy consumption in Room 3 (without film coating) was 1082000kJ. This indicates that film coating room has about forty percents energy for heating could be saved in winter in this region. Figure 3 reveals that the measured heating energy consumption profiles in one-minute interval on Day 1. The trend of two curves in the Figure 3 shows that the energy consumption of the room with solar-control film would be only a half of that of without film coating in most of the time. Thus, energy saving trend is observed with the use of solar control film in winter as opposed to our common sense. This preliminary study finds that, in winter when very low solar radiation transmitted into indoor environment, the effect resistance of solar energy of film coating can be neglected. Instead, the film can act as a layer to prevent heat to transmit to outdoor, more or less like greenhouse effect. Since the measuring days last only a short period, further study should be carried out to identify the exact data that how much energy can be saved via this kind of greenhouse effect.

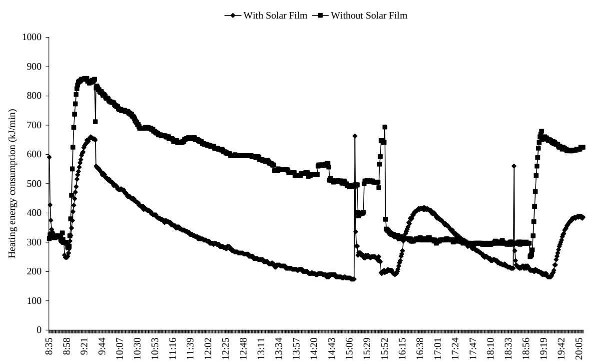

Fig.3 Measured heating energy usage (one-minute interval) profiles on Day 1

4. CONCLUSION

Based on the experiment results and analysis above, two initial conclusions about the illumination and energy saving performance were made:

1) The solar control film can reduce even larger amount of daylight illuminance when the outdoor

illuminance admitting through the glazing is below 1000lux than when it is over 5000lux: the result of this experiment showed the average visible light transmittance for the film was 49.8%, far lower than the previous study of 76.7%.

2) As the energy saving performance is concerned, the room with the solar control film adopted could save about forty percents energy for heating in winter in this region. This indicates that in winter when very low solar radiation being transmitted into indoor environment, the effect resistance of solar energy of film coating can be neglected. Instead, the film can act as a layer to prevent heat to transmit to outdoor, just like greenhouse effect. However, the above preliminary findings are subject to further verification of any measuring equipment error and data measurement procedure.

Since this is a part of result of a much larger project, the data presented in this paper need to be further confirmed, further study should be carried out to identify the exact data that how much energy can be saved via this kind of greenhouse effect.

ACKNOWLEDGEMENT

This study was financially supported by The Hong Kong Polytechnic University (G-U087).

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